

# High-energy 2- $\mu$ m Laser Development

*NASA Langley Research Center*

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Bo Trieu, U. N. Singh<sup>a</sup>, M. J. Kavaya<sup>a</sup>

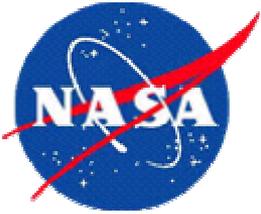
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3<sup>rd</sup> ESTO Conference

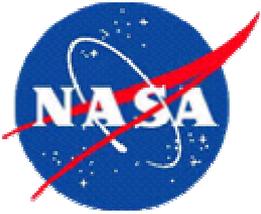
24-26 June 2003, University of Maryland



# Outline

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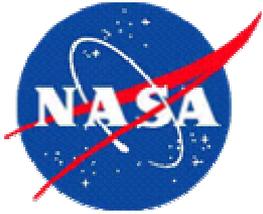
- **Partially Conductively Cooled Oscillator**
  - For use as a test-bed for related laser technology development including the CCLH
  - Develop for use as a ground and airborne wind Lidar transmitter
- **Double-Pass Amplifier**
  - To demonstrate high energy, high efficiency 2-micron laser technology
- **Fully Conductively Cooled Laser**
  - To demonstrate space qualify-able conductively cooled laser technology



# Operational specifications

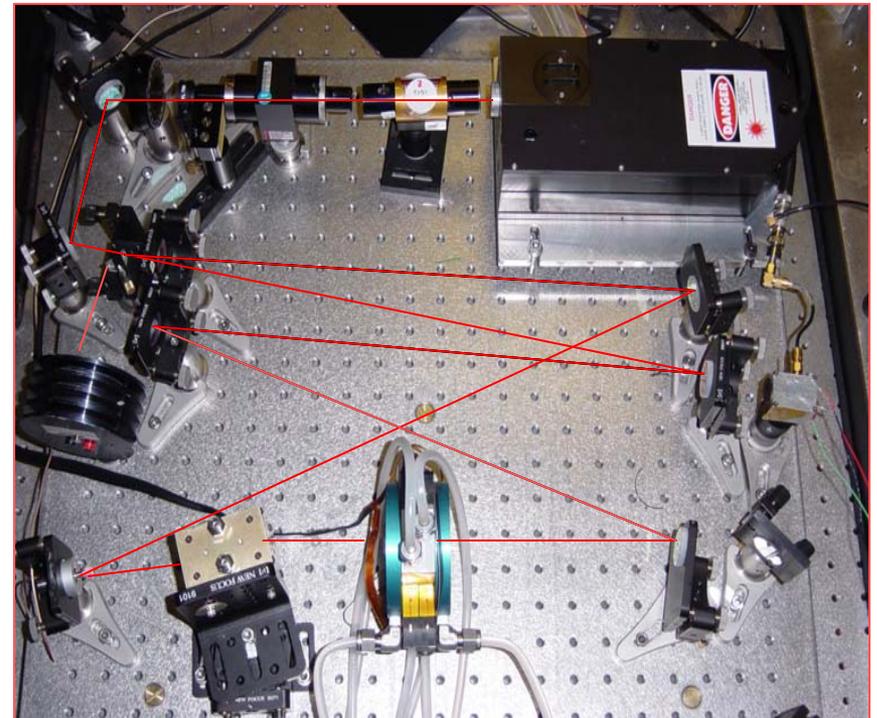
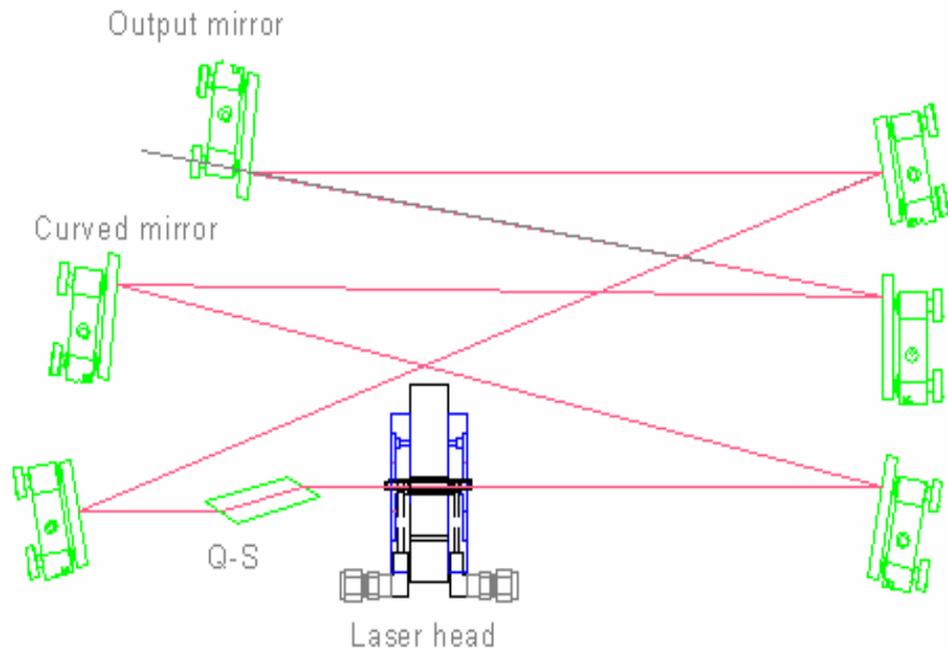
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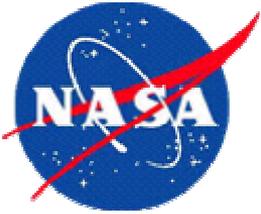
Laser material	Ho:Tm:LuLF
Output energy	100mJ
wavelength	2.053 $\mu$ m
Pulse repetition rate	10 Hz
Pulse length	150 ns
Laser operating mode	Single frequency
Beam quality	$M^2 < 1.3$
Operating temperature	15 $^{\circ}$ C



# Experimental Setup

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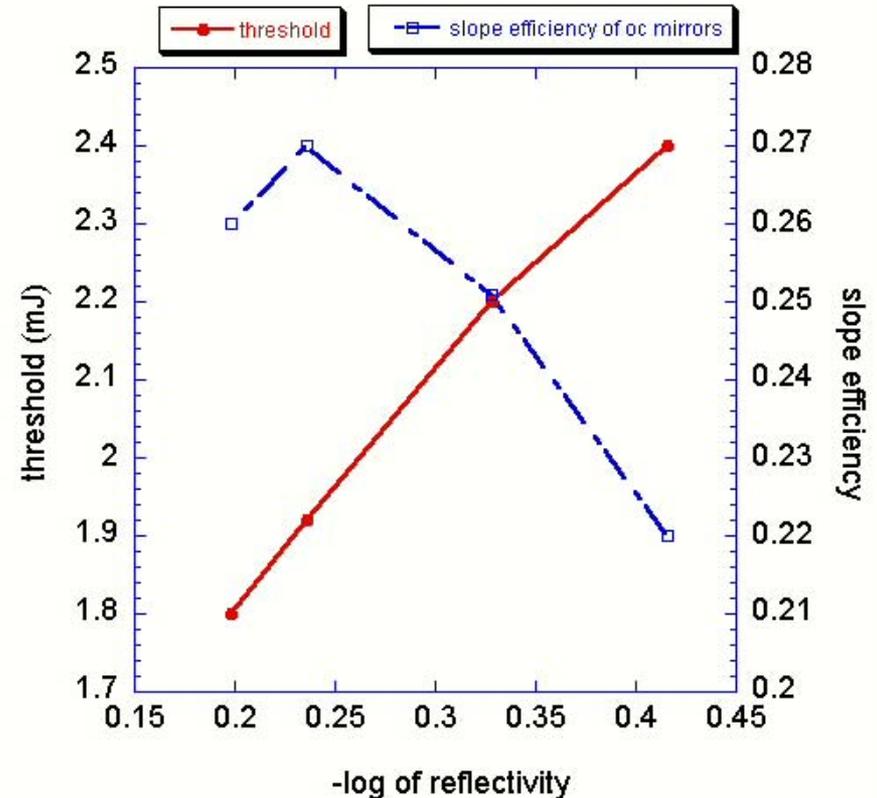


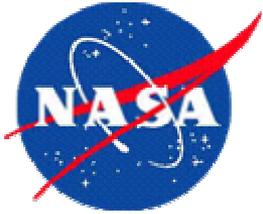


# Output coupler selection

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- The threshold grows linearly as a function of the negative log of reflectivity. However, the slope efficiency is the highest if a 79% reflectivity mirror is used.
- The output coupler was selected by testing various output reflectivity mirrors ranging from 66%R to 87%R.
- 66%R and 72%R mirrors are used for this experiment to reduce fluence in the resonator.



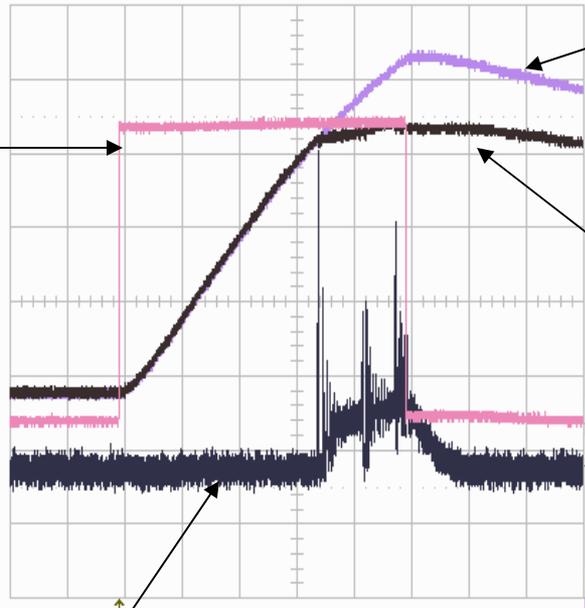


# Population dynamics of Ho

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18-Sep-02  
18:09:31

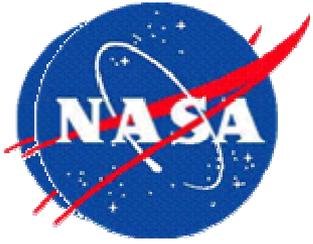
Pump  
pulse



In the absence of lasing, the population build-up continues until the pump is removed

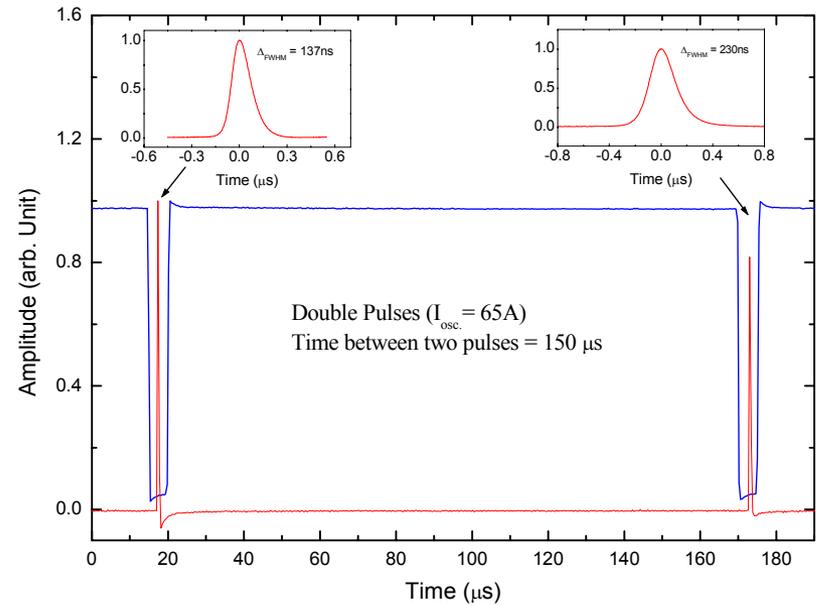
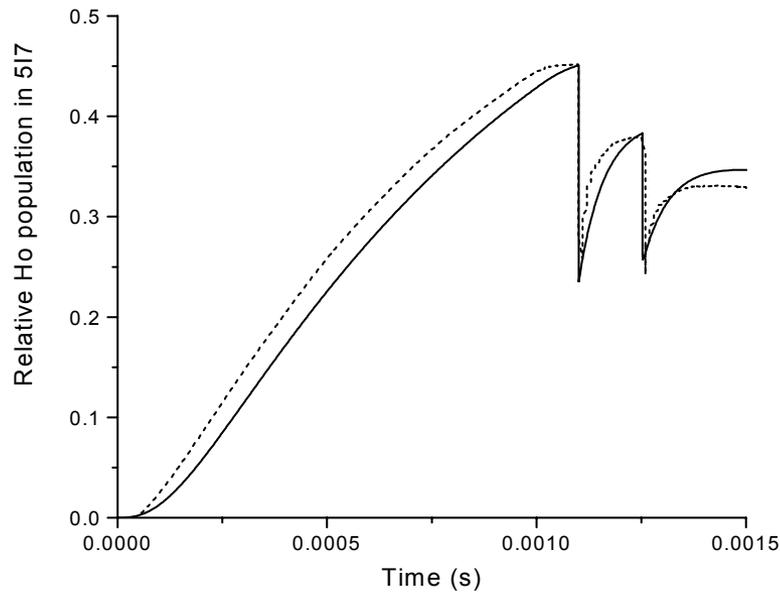
Ho  $^5I_7$  population is clamped at threshold during normal mode operation

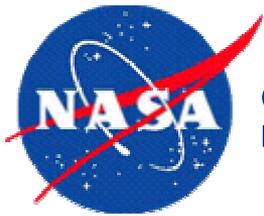
Normal mode  
waveform



# Double pulsed 2- $\mu\text{m}$ laser operation

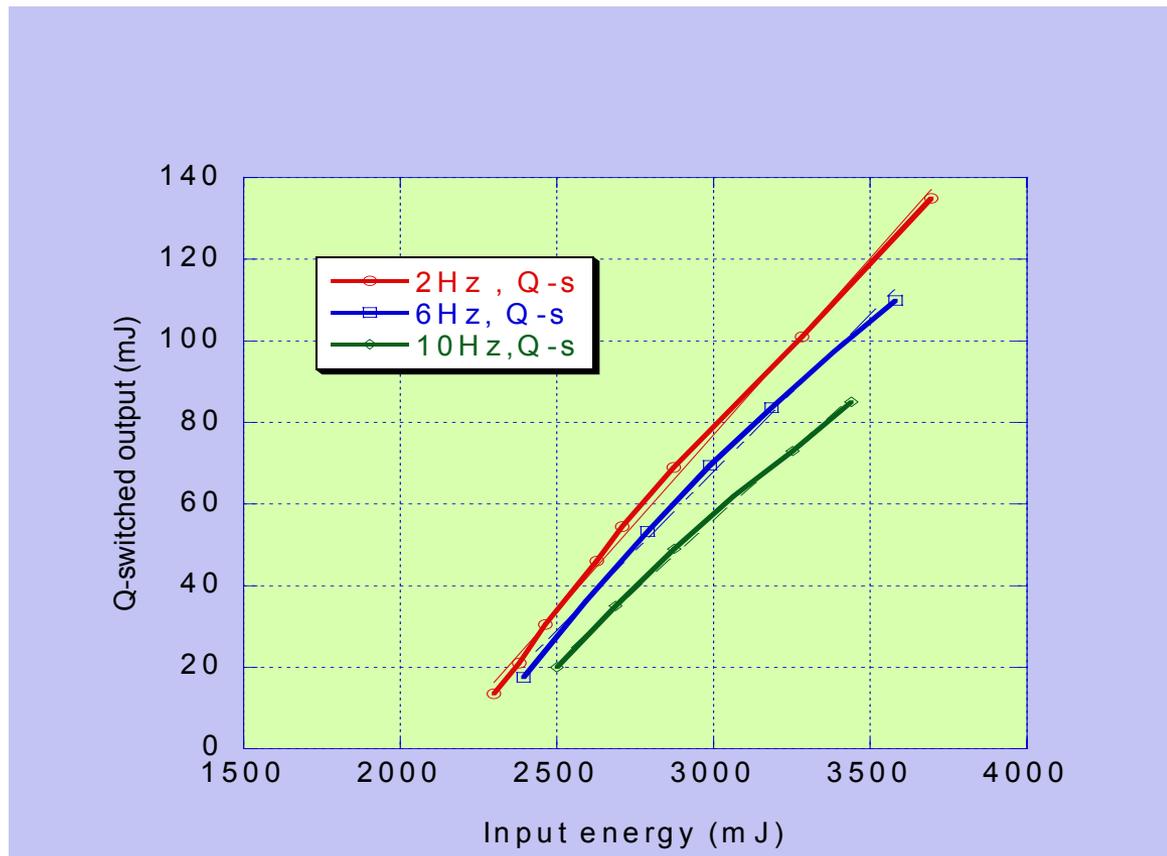
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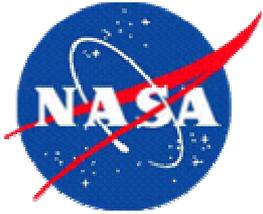


# Single Q-switch pulse performance

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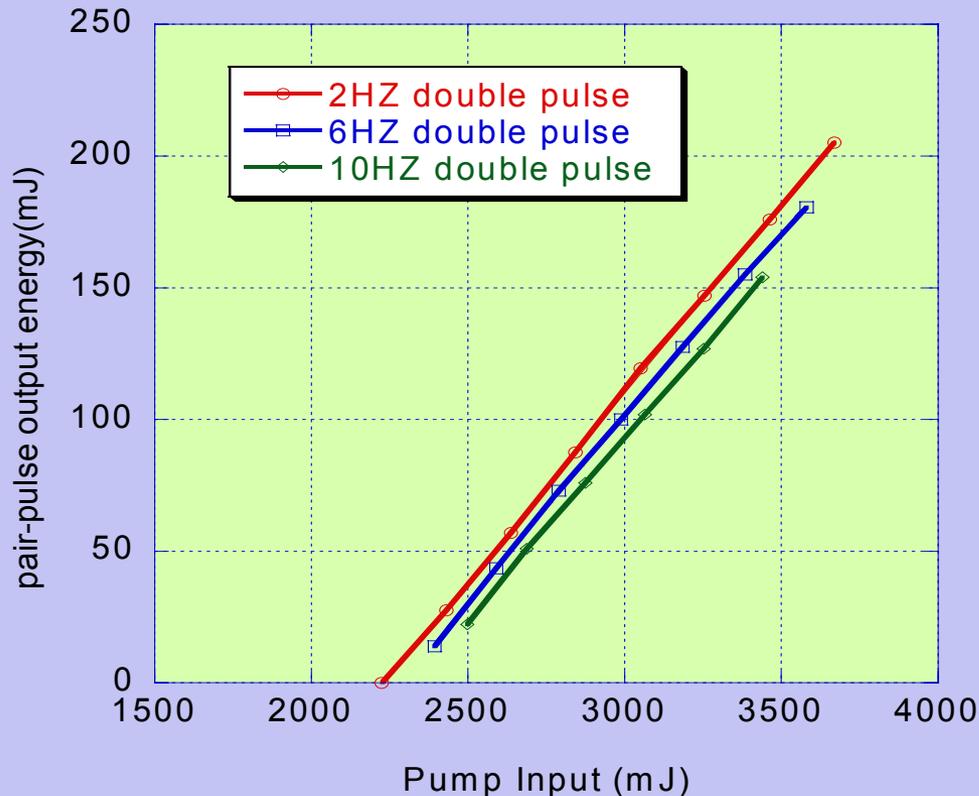


- Slope efficiency for 2, 6 and 10 Hz - 9%, 8% and 7% respectively

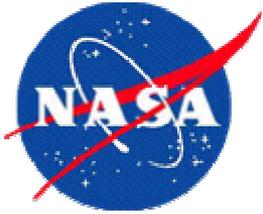


# Double pulse performance

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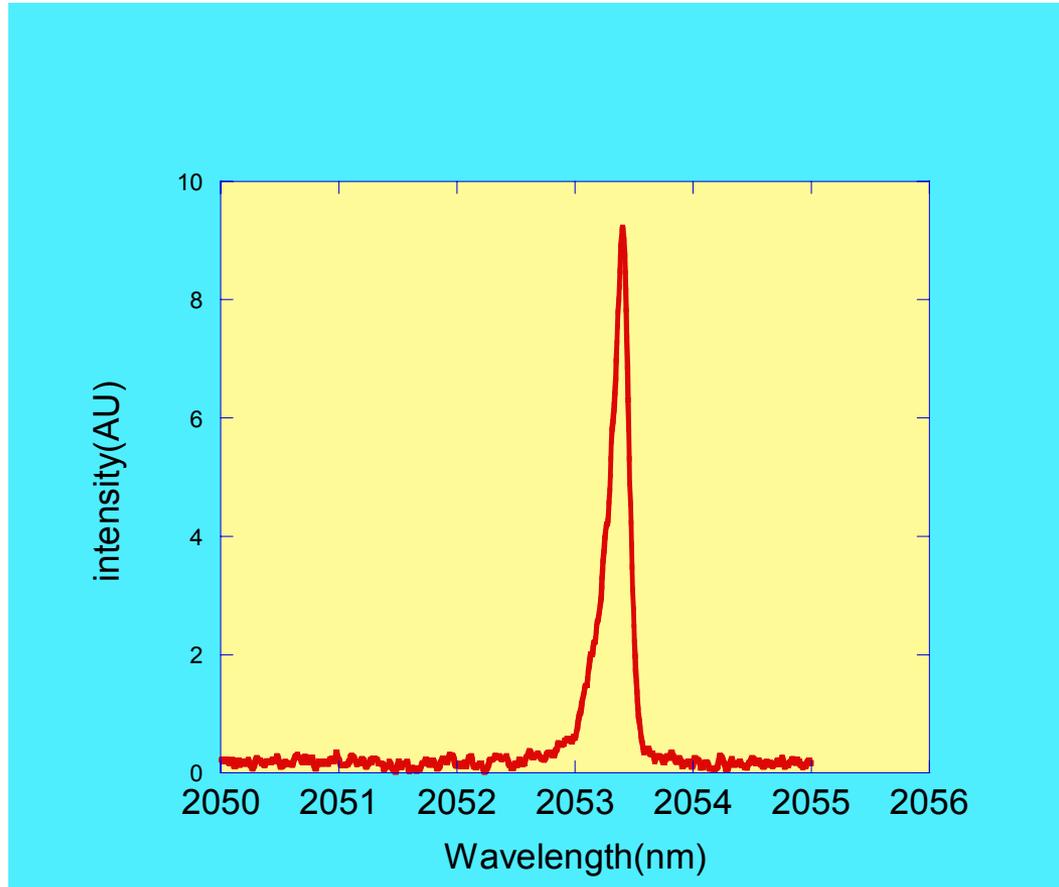


- Slope efficiency for 2, 6 and 10 Hz is 14.3%, 14% and 13.8% respectively

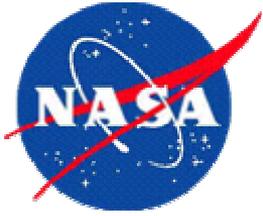


# Ho:Tm:LuLF wavelength

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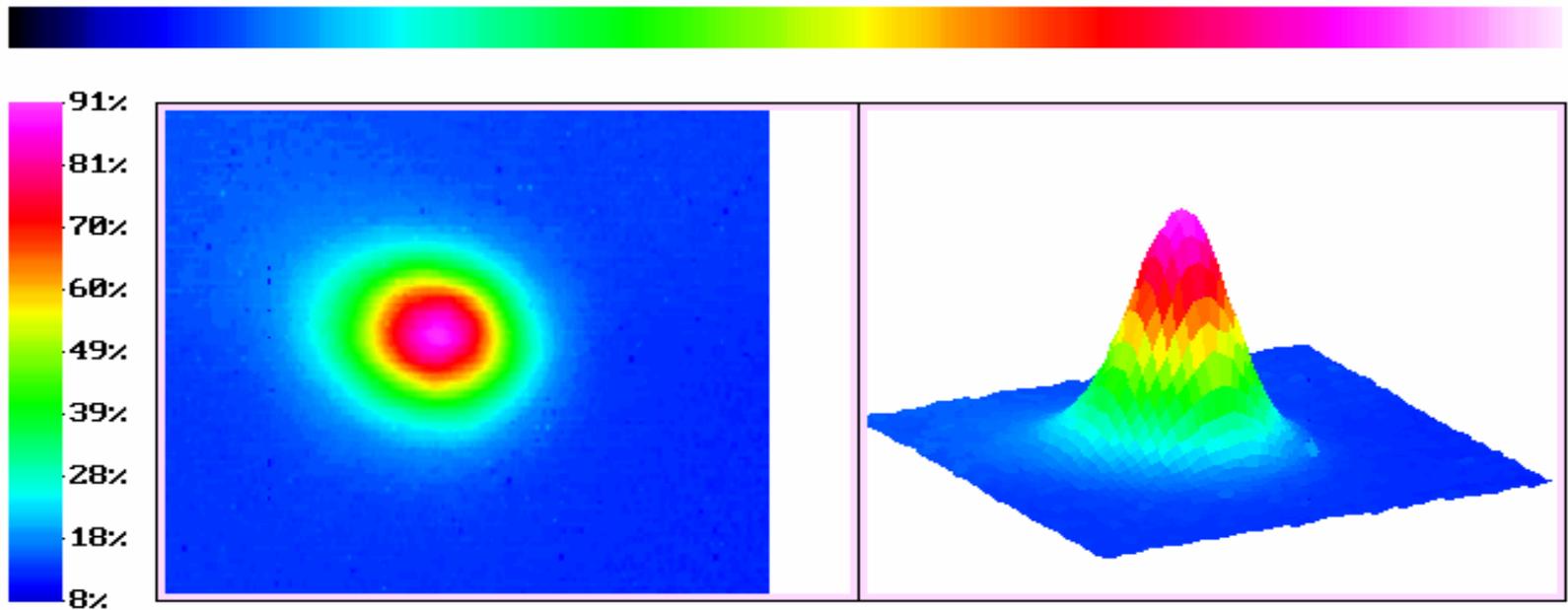


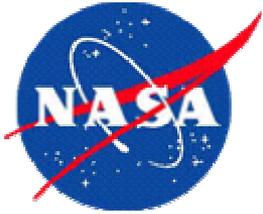
- Ho:Tm:LuLF has transition around 2067nm and 2053 nm. At higher than 80% R output mirror it tends to lase at 2067nm.



# Near-field Beam Profile

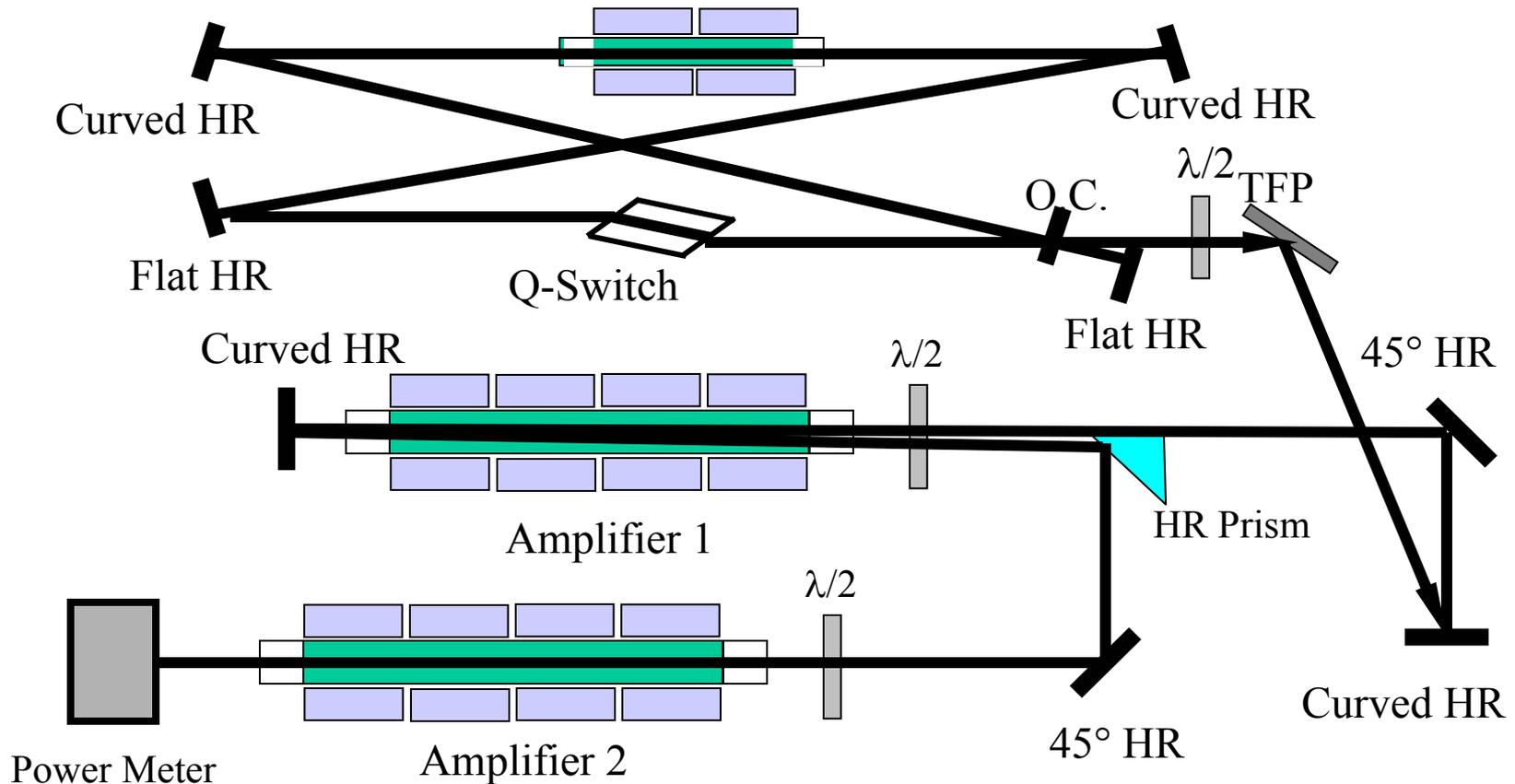
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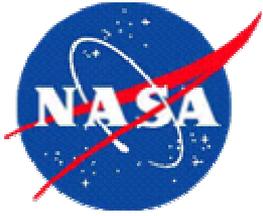




# Tm: Ho: LuLF Laser Oscillator and Amplifier

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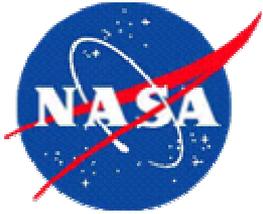




# Oscillator and Amplifier Setup

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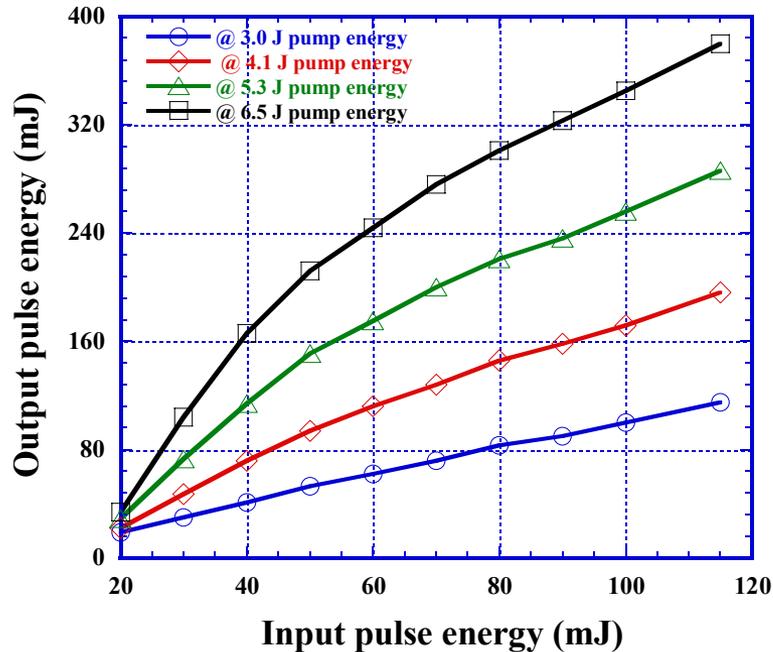


# Performance of Laser Amplifiers

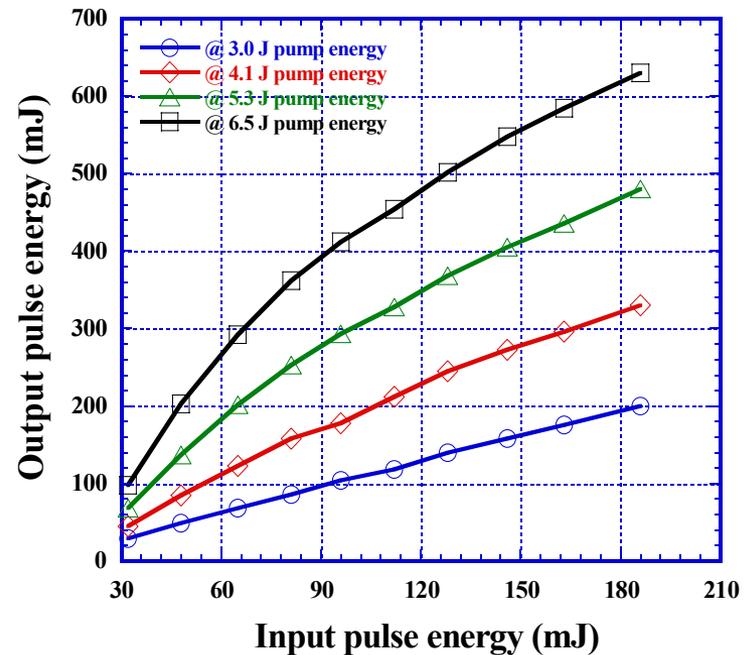
## Amplifier One @ Q-switch mode operation

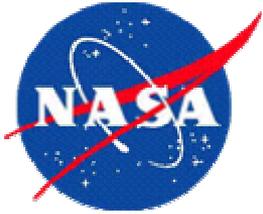
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### Single pulse double pass



### Double pulse double pass



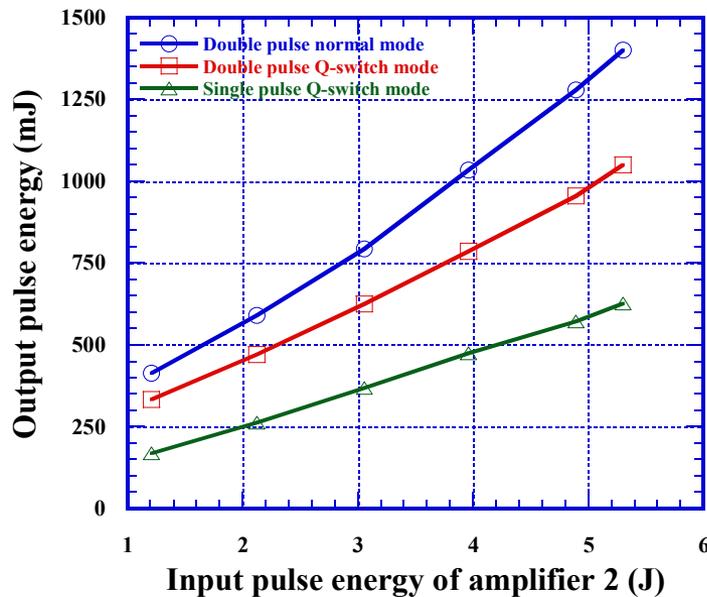


# Performance of Laser Amplifiers

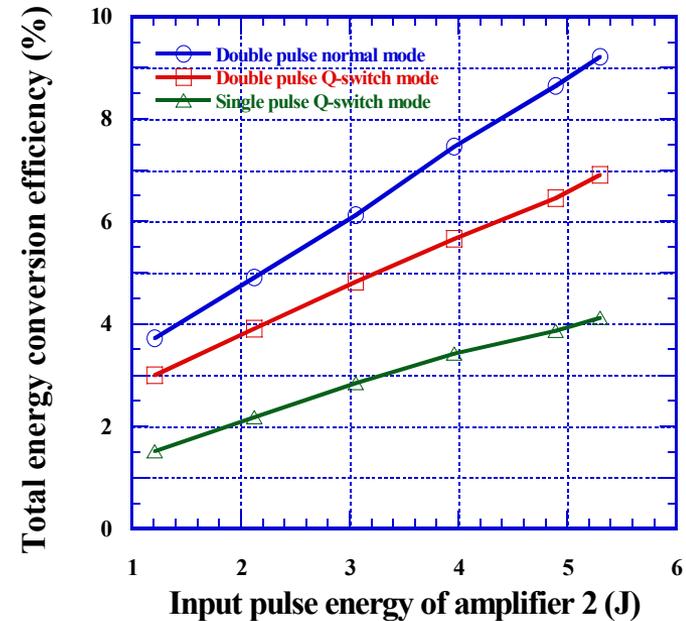
## Amplifier Two (single pass)

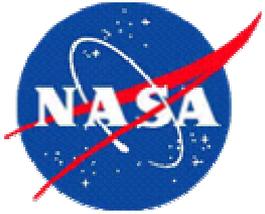
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### Output Energy



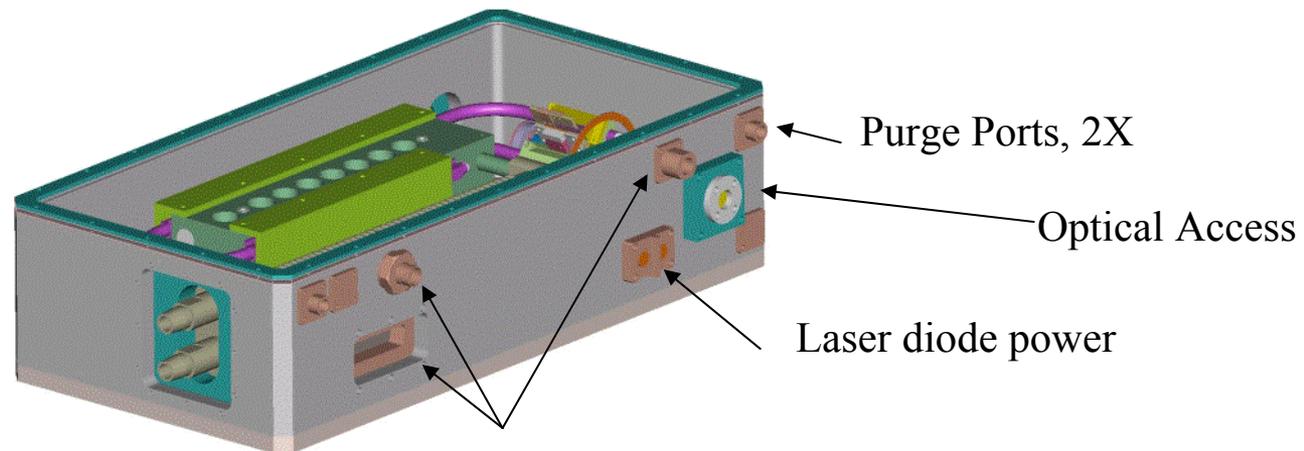
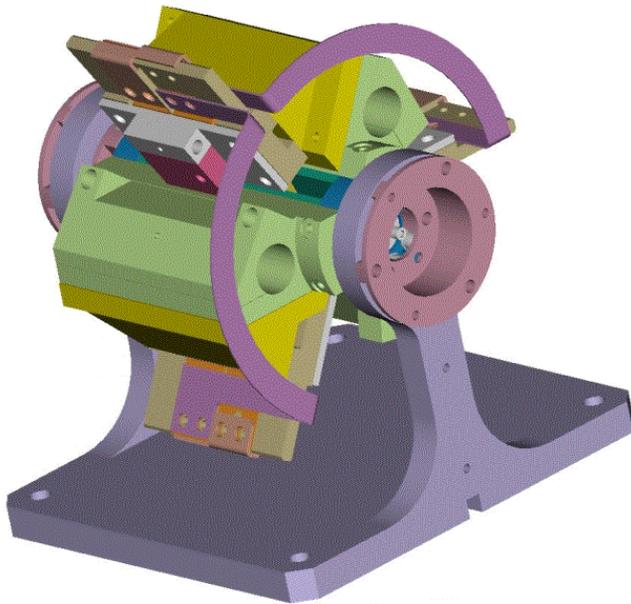
### Efficiency

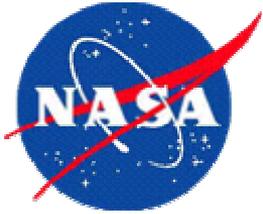




# Fully Conductively Cooled Laser Pump Head Assembly

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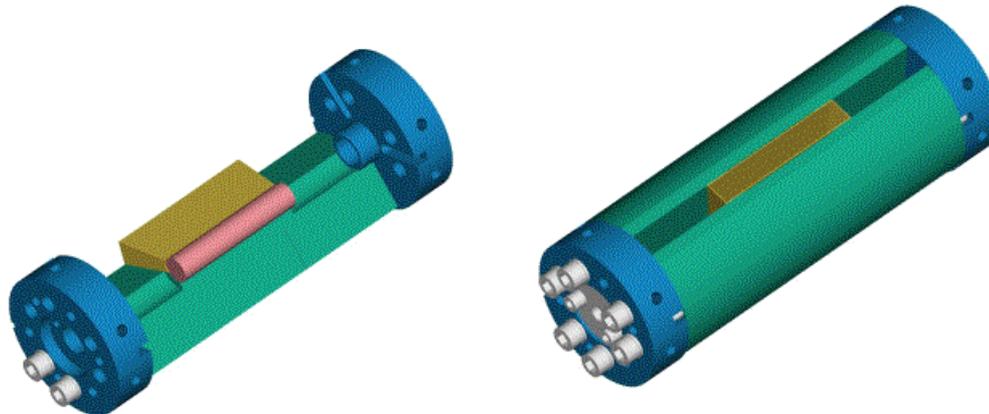




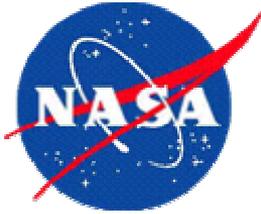
# MECHANICAL DESIGN GUIDELINES

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- FOCUS ON ROBUST AND FLEXABLE DESIGN
  - MODULAR
  - EASE OF INTEGRATION AND DEINTEGRATION
- INCORPORATE OPTIMUM COUPLING OF DIODES TO ROD
- MAXIMIZE THERMAL MARGINS FOR CHARACTERIZING ASSEMBLY AND BEST CHANCE FOR SUCCESS



Single electroformed waveguides

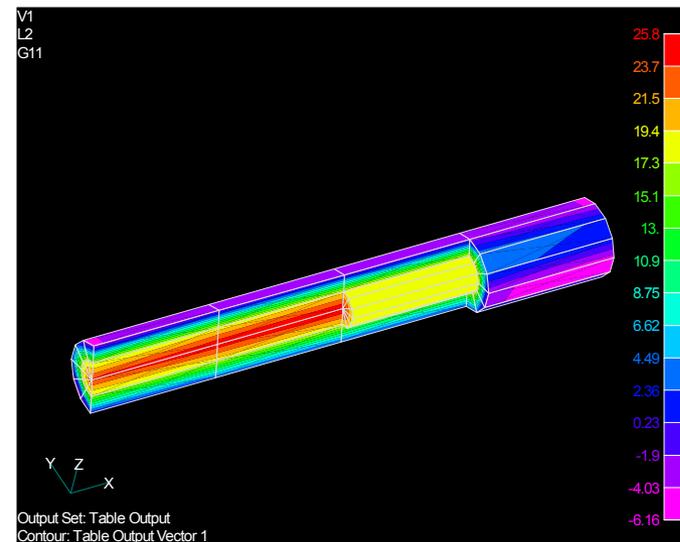
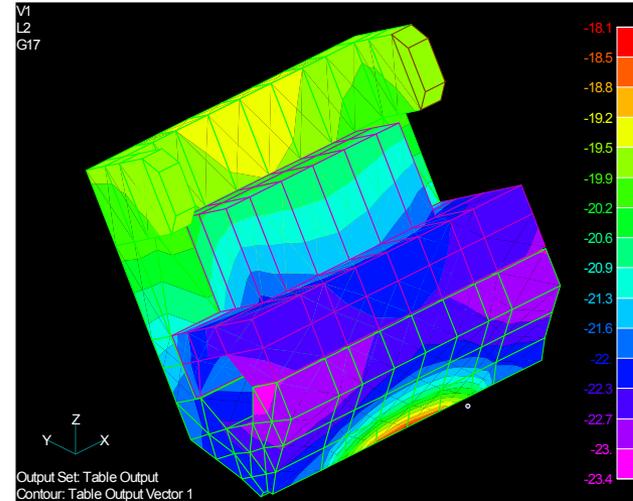


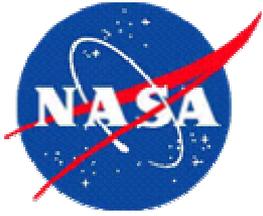
# Fully Conductively Cooled Laser

## Thermal Analysis

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- INITIAL TEMPERATURE PREDICTS
  - ROD CENTER TEMP 25C
  - ROD SURFACE TEMP -6C
  - $\Delta T$  ROD CENTER TO EDGE ~31C
  - $\Delta T$  ACROSS ROD BOND ~14C
  - $\Delta T$  FROM ROD BOND TO HP BOND IN MOUNT ~ 4C
  - $\Delta T$  ACROSS HP BOND ~ 2C
  - $\Delta T$  FROM HP SURFACE TO VAPOR NODE ~ 10C

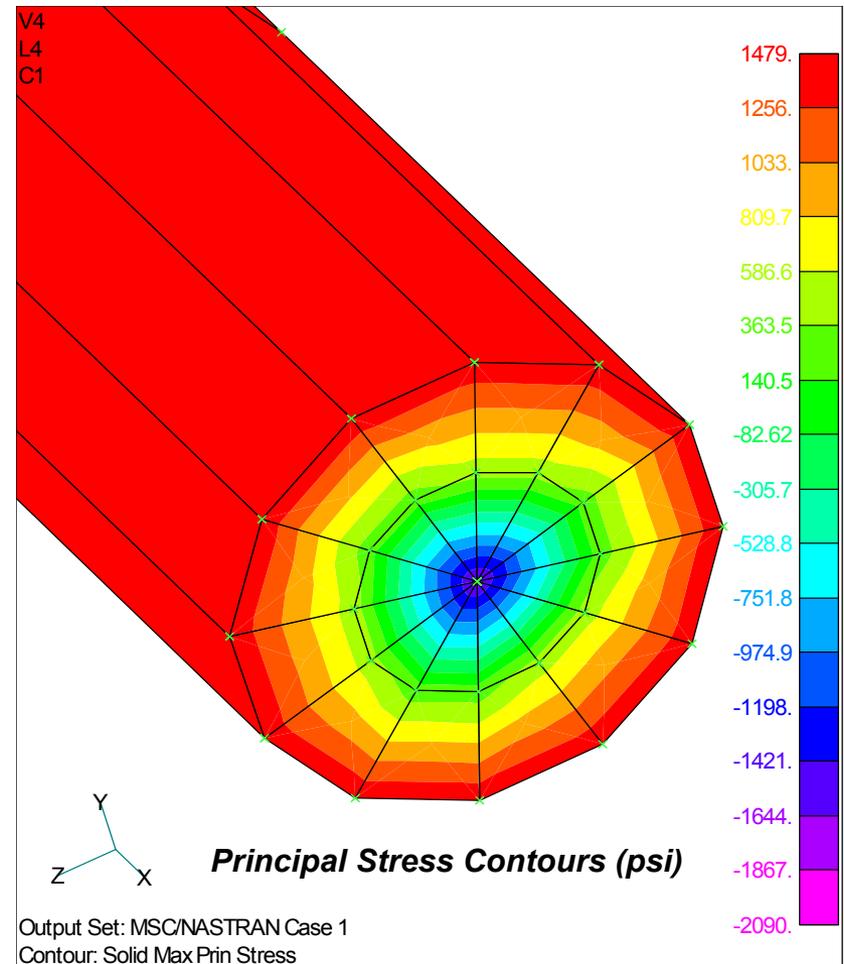


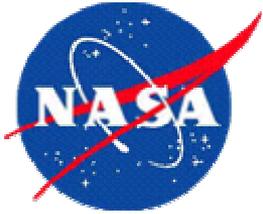


# Fully Conductively Cooled Laser Crystal Thermal Stress Analysis

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- The maximum compressive stress is about 2100 psi at the rod centerline and the Maximum tensile stress is about 1480 psi at the rod periphery
- A simple comparison of the maximum predicted stress of 2100 psi to the Material Strength of 4780 psi indicates that rod structural integrity is probably not undermined.





# Summary

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- Demonstrated a diode-pumped, room temperature Q-Switched, 135 mJ laser operating at  $2.0536\mu\text{m}$ . This oscillator is currently used in the validation lidar (VALIDAR) as a wind lidar transmitter.
- Demonstrated a master-oscillator-power-amplifier (MOPA) system. The system has two amplifiers and the first is double-passed and the second is single-passed

	Single pulse	Double pulse
Output pulse energy (mJ)	> 600	>1000
Total optical efficiency (%)	~ 4 %	~ 7 %

- Completed optical, thermal and stress analysis, and mechanical design of a fully conductive cooled laser head. Fabrication is scheduled to be completed by August 2003.